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Economic analytical methods for work-related MSD cost prediction

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Abstract

Today's changing work environment focuses on work organization and new forms of cooperation (outsourcing, decentralization of resources, introduction of new technologies, etc.) [1,2]. Organizations sustainable development is linked to the business success in the long-term run. It can be achieved with the help of organization`s social and technical development, healthy work environment and competitive workers. Musculo-skeletal disorders (MSD), including lower back pain, arm and neck muscle or tendon sprains and joint diseases have a significant impact on employees' workability not only at the individual level but also at national perspective [3,4]. MSD affects efficiency, productivity and overall quality in every organization and labor market [5]. The aim of research is to discover most appropriate economic analytical methods for work-related MSD cost prediction in Latvian enterprises. This research focuses on the analysis of literature of various economic analytical methods for work-related MSD cost prediction at the organisations. Experts in ergonomics field suggests dividing ergonomic intervention costs to avoid MSD into four main categories [6]: Staff, equipment and material, reduced production and sales volume, overhead costs. World literature analysis shows that by increasing ergonomics preventive and assessment costs, considerably decreases costs of human and technology errors in the processes. Hence, it is possibility to gain additional profit that could be diverted for further preventive actions in order to continuously minimize MSD [7,8,6]. The combination and modification of economic analysis methods of economic loss mathematical calculations [9,10] and Washington State Ergonomics Cost Benefit Calculator is suitable for work-related MSD cost prediction and ergonomics solution cost and benefit analysis in European enterprises.

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1. Introduction

Contemporary rapid changes in work content have caused challenge and stress in socio-technical system of many enterprises. Today's changing work environment focuses on work organization and new forms of cooperation, for example, outsourcing, decentralization of resources, introduction of new technologies, etc. [1,11,12]. Creation of qualitative work places, emphasizing human centered approach and implementing ergonomics process in business management, is one of the main conditions for sustainable development of an enterprise. Thereby work in safe and ergonomically favorable conditions is not only human but also economic necessity.

Unfortunately work related musculo-skeletal disorders (MSD), including lower back pain, arm and neck muscle or tendon sprains and joint diseases have a significant impact on employees' workability not only at the individual level but also at national perspective [3,4]. MSD affects efficiency, productivity and overall quality in every organization and labor market [5]. The cost of MSD to employers is significant because it can result in cost component being lost time from work. Over 45 members of the European Union workforce have a long-standing health problem or disability that affects their ability to work, and MSDs – conditions affecting bones, joints and connective tissue – account for a higher proportion of sickness absence from work than any other health condition [13]. The European Working Conditions Survey has shown that 24.7 per cent of workers across the EU report suffering frequently from backache and 22.8 per cent from muscular pain [14]. The effects of incapacity and pain from work related MSDs can affect several aspects of an individual’s performance at work, for example, stamina, cognitive capacity or concentration, rationality, mood, mobility etc. Cammarota in the research proves that estimated cost that derives from MSD problems to society states from 0.5 to 2.0 per cent of GDP [15].

Considering that in nearest future with prospects for an ageing workforce, reduction of physical activity, and a growth in obesity and smoking rates in the general population, the effects of MSDs could negatively influence the quality of working life, even loss of the job. Job loss has serious financial and health consequences for individuals as studies have shown widespread deterioration in aspects of physical and mental well-being among those who lose their jobs that can persist for many months [16,17,18].

MSD prevention needs an application of ergonomics [19] Adams proposes that ergonomics program should involve a reactive program of identifying, analyzing and correcting “problem jobs”, and a proactive process of integrating ergonomics into process and product design [20]. It has been a challenge to provide exact work related musculo-skeletal disorders (WRMSD) financial calculation methods at the enterprises, because it involves various factors that influence the accuracy, reliability and consistency of the data [21] and organizations are aware of sensitive data leakage. Several researches focuses on establishing the cost and benefit calculations for work related MSDs, some of them are more oriented on ergonomics intervention costs and benefits that minimizes MSDs, but others are connected with costs of MSDs influence on business indicators [22]. Hence, the aim of research is to discover most appropriate economic analytical methodology for ergonomics solution cost and benefit analysis and work-related MSD cost prediction in European enterprises.

2. Methods

This research focuses on the analysis of literature of various economic analytical methods for work-related MSD cost prediction, cost and benefit analysis of ergonomics solutions at the organisations. The monographic research method and comparison method were used to analyze theoretical application of the MSD cost calculations and tools.

3. Results and discussion

Measures of ergonomic intervention consist of purposeful activities in order to make changes and make them stable and long-term. Specialists in the area of ergonomics are not always able to persuade organisation managers on necessary financial investments in introduction of ergonomic solutions, if economic benefit is not proved. A researcher in ergonomics, H. Hendrick, working out measures of ergonomic intervention, pointed out that it is important to determine costs and benefits to be acquired, which should be measurable [6]. He discovered that ergonomic intervention, which is aimed at introduction of ergonomic solutions, increases efficacy of the organisation by 60...90% [23,24].

Ergonomics intervention in organisations improves efficacy of organisation's functions and ensures wellbeing at work, which promotes achievement of positive process result and client's satisfaction. It should be noted that ergonomics intervention in organisation management simultaneously with advantages can cause also negative side-effects as well, which need to be coordinated and monitored. Such side-effects basically can be related to manufacturing enterprises (for example in assembly line), introduced into production, or automatic system (See Table 1).

Table 1. Advantage and side-effects, introducing ergonomic solutions in production technologies.

Advantages	Side-effects
• Work productivity and process performance increases • Supply period of parts and raw materials decreases • Manual work in moving heavy loads decreases • Rotation of employees is possible • Saved time for frequent hand and leg movements • Number of damaged products and clients' complaints decreases • Amount of spare stocks (raw material, materials, etc.) decreases	• Errors are possible in automated technological system due to corrosion or aging • Investment costs grow • Effect of cognitive ergonomics increases (concentration necessary, incl. visual and hearing load) • Process performance decreases during stoppage of automated line

Negative side-effects can cause stoppage of the equipment and often it is related with human errors (improper professional education, insufficient training for work techniques) and technological errors (incl. equipment corrosion or aging), as well as with improper or insufficient control (delayed technical service and other reasons). In automated processes operators have higher effect of cognitive ergonomics (higher level of concentration, incl. vision and hearing stress, etc.). At the same time it should be noted that usually during stoppage of production equipment employees are involved in physically hard works, which can cause health damage caused by overload. Such drawbacks or negative side-effects can appear also in other processes in which production technologies are being changed or reconstructed, and they should be taken into consideration in cost and benefit analysis for ergonomics implementation and MSD reduction.

According to the world leading ergonomists [6,25] costs of ergonomic measures or solutions are easily understandable, as they are fixed financial means for improvement of the used equipment, acquisition of more modern equipment, training of employees, etc. However, it is more difficult to evaluate benefits, as they are related to decrease in costs due to illnesses of employees, reduced losses due to unproduced goods within a certain period, etc. In addition, there are benefits that are difficult to convert in monetary value – satisfaction of employees, loyalty to the enterprise, etc. Costs of ergonomic solutions can be single (capital investments) and long-term. If the equipment and spare parts are produced on the spot, the costs are determined by using accounting data and costs on personnel [26]. In a well-organised work place employees can achieve higher work results with less effort. To reach such goal, financial investment is not significant, however, from organisation management it requires careful planning and consultations with employees, which results in provision of employees' wellbeing and increase in productivity.

Most commonly measures for ergonomics improvement decrease exploitation costs and therefore in calculations they appear as benefits. Sometimes measures for ergonomics improvement are related with a short-term stoppage of the processes. In its turn, it can cause decrease in the amount of production or sales in a certain period of time. Hence, calculating costs, one should keep in mind the costs of this not obtained benefit as well.

The summary of the most essential economic benefits from ergonomic intervention as implementation of solutions for MSD reduction are shown in Table 2 [6,25].

In order to ensure successful production processes, careful planning and organisation of them, consulting the employees, is of most importance. Organisations usually choose low cost improvements, which can be easily worked in the existing work methods and equipment and implementation of which is possible applying already aprobated materials and knowledge. However, scientific studies have proved that macro-ergonomic solutions result in improvement of the production process, human safety, and organisation's operation proceeds effectively [27]. Macroergonomics, which includes elements of microergonomics as well, is systematic, continuous, human-centred, and one of its basic methods is cooperation ergonomics, in the framework of which employees, at all organisation

Table 2. Division of benefits from ergonomic intervention.

Benefit	Manifestations of economic benefit
Personnel	• work performance improves • work faults reduce • less accidents and illnesses at work • time devoted to training decreases • design of workplaces, skills, etc., improves
Equipment and material	• performance of equipment increases • procession of raw materials improves • equipment, etc., improves
Amount of production and sale	• less defective articles • product quality grows • amount of production increases • amount of sale increases
Other benefits (indirect)	• loyalty of employees • satisfaction of employees • organisation image improves

levels, are involved in the process [28]. Thereby, it should be started with ergonomic risk analysis and management that involves such ergonomics risks as force, repetition and postures.

Ergonomics risks are among the most common risks for MSD at the work environment. These risks, in point of fact, can be monitored – if legal base of risk assessment, as well as methodologic provision and assessment procedure are established, and special requirements for risk reduction have been determined [9]. In order to carry out effective activities in MSD risk reduction, perfection of processes, as well as to make changes in processes and promotion of safety of employees, it is necessary to summarize the available data on MSD risk possibility, to analyse MSD risks, to work out actions for their prevention or reduction, as well as to supervise and revise risks continuously [29,30]. Recommendable actions for risk management are shown in Fig. 1.

Nowadays, in the process of risk management, employees' participation is of high importance. It requires additional knowledge of the work to be done. Knowledge is related with continuous education on possible MSD risks and their reasons, etc. Therefore, it is important to prepare employees for the coming changes so that the common performance of the organisation system would be continuously adjusted and improved, and long-term efficacy of the organisation ensured. Correctly evaluated risk level will result in more accurate estimation of MSD impact and prevention costs.

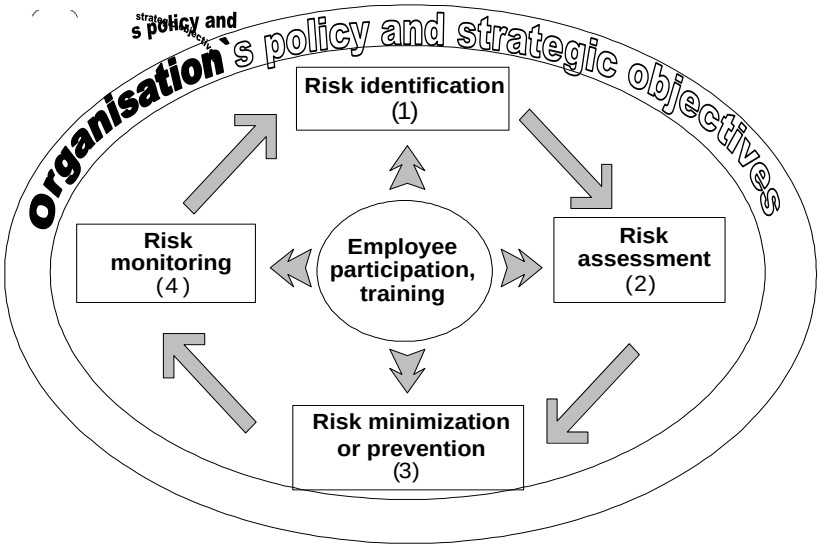

Fig. 1. Model of ergonomic risk management for MSD reduction. [10]

It should be kept in mind that introduction of any ergonomics changes requires careful assessment of them, attraction of resources so that these changes would be adjusted adequately to the certain person and workplace. It should be explained to the employees that the possible problems, related with the changes, would be justified greatly with the results of changes. Participation in changes is based on employees' experience in order to identify timely the existing problems and to plan ergonomic intervention programme [31,19].

For assessment of costs-benefits of ergonomics intervention into organization processes the Washington State Ergonomics Cost Benefit Calculator (WSECBC) can be used. Calculations are based on a review of 250 case studies in which organizations reported the outcomes of ergonomics programs and individual solutions [32], were calculations from increasing productivity and profit through health and safety are considered based on Oxenberg findings [33]. Application of WSECBC can be done for organizations in various branches by adjusting the original WSECBC version to local country specifics [10], for example in diverse manufacturing processes in woodworking, construction and metalworking enterprises. Benefit from ergonomics integration and MSD reduction can be mathematically evaluated, taking into account reduction of number of employees' complaints, clients' claims, as well as increase in production, costs for implementation of ergonomic solutions, annual savings, etc. Cost-benefit assessment programme WSECBC calculates long-term economic effectiveness, relating it to 1...5-year period. The characteristic example of effectiveness of ergonomics improvements in relation to MSD reduction is shown in Table 3.

Table 3. Example of calculated benefits from ergonomic solutions using WSECBC.

Processes	Implemented ergonomic solutions	Calculated benefit, USD	
		1st year	5th year
Woodworking:			
Plank production	New automated sawn timber sorting line, training of employees, introduction of lifting aids	150 000	650 000
Construction:			
Road construction	Introduction of lifting aids, rotation of employees, acquisition of new road covering machines.	120 000	540 000
Demolition of buildings	Acquisition of demolition tools, lifting aids, rotation of employees.	25 000	115 000
Metalworking:			
Metal melting	Acquisition of new melting equipment with capacity of 4t a day, auxiliary equipment for metal bars, automation of preparation feeding, rotation of employees.	18 000	85 000
Production of metal bases	Modernisation of finished product assembly process, auxiliary tools for lifting and moving of preparations, rotation of employees.	12 000	54 000

In example (Table 3) calculations of the computer programme show that annual benefit from introduction of ergonomic measures significantly exceeds costs, in addition, benefits are increasing from year to year. In cost-benefit calculation with *WSECBC* method, the computer programme lets calculate also reduction (%) of negative impact of ergonomic risks on employee's health and safety at work, provided that ergonomic measures are introduced. The example of reduction (mean values in certain branches in Latvia) are shown in Table 4.

Table 4. Example of calculated reduction of ergonomic risks using WSECBC.

Type of solution	Reduction of ergonomic risks		
	Construction	Woodworking	Metalworking
Eliminated negative impact of risks	60%	70%	76%
Reduced level of risk impact	35%	40%	48%
Reduced time of risk impact	12%	15%	18%
Relieved hard manual work	12%	10%	15%

Costs for MSD prediction and preventive measures can be calculated also by regular mathematical formulas. The profitability E in stated period of time if improved working conditions for minimizing MSD can be determined [34,29]: $E = \Delta S + \Delta P + \Delta L$ (USD), where ΔS – margin of work accidents, MSD expenses before and after stated period of time, ΔP – margin of profit increase considering workers workability increase and work environment improvement after MSD minimization, ΔL – margin of expenses of recompense of MSD before and after stated period of time. Annual improvement effect (EG) can be calculated: $EG = E - R$ (USD), where E - the profitability if improved working conditions and reduced MSD in stated period of time, R – investments to realize MSD minimization improvements, that can be calculated as $R = \varphi A - L$ (USD), where A − capital investments (for example, new ergonomics technology, improved workstations, etc.) φ − coefficient describing efficiency of capital investment, L − additional costs for the improvement complex realization (for example, training for proper lifting and moving, implementation of safety culture, etc.). If the calculations are made, the efficiency of MSD reduction improvements can be calculated by formula: $EK = (E - L)/A$. The payback time of MSD reduction investments can be predicted as T= 1/EK.

The example of calculation summary of ergonomic solutions in manufacturing enterprise is shown in Table 5.

Table 5. Example of calculation summary for ergonomic solutions.

Total losses ($S = \sum_{i=1}^{6} S_i + Z_n$)	Before ergonomics implementations	After ergonomics implementations
	560000 USD	155800 USD
After implementation of ergonomic solutions in "Ergo-process"		
Annual economic effectiveness or advantage	Effectiveness of investments	Period of investment payoff
230900 USD	1.3	0.77 years

As represented in Table 5, data of the studied enterprise suggest that after ergonomics improvements for MSD reduction in manufacturing production has increased by 43% and profit has grown (ΔP = 30000 USD). Taking into account this profit, economy of means, expenses for maintenance of ergonomic measures (maintenance staff, equipment service, acquisition of spare parts, etc.), annual economic effectiveness was determined in the amount of 230900 USD. The calculated absolute economic effectiveness of investments EA = 1.7, which shows that investments in ergonomic solutions have been effective. Period of investment payoff T is comparatively short – less than 1 year, as T= (1/EA)=1/1.3=0.77.

The research group in part of EU-OSHA project on economic incentives studied 14 various case studies and found out that economic incentive schemes are feasible in a variety of socio-economic contexts [35]. In case studies the methodology was analyzed and cost-benefit analysis was carried out by calculating the ratio between the costs of the incentives and also the benefits from prevented accidents and sick leave, including MSD prevention. As Finland department of occupational health proved, lost labour input due to WRMSD affects organization sustainable development and at the same time causes national economic consequences [36]. Total loss of Finland national economy exceed 25 billion USD per year due to occupational accidents and diseases, disability pensions, sick leaves, presenteeism and cost of medical care and WRMSD has significant impact. Hence, organization managers should gain understanding by good practice examples that motivate firms to promote ergonomics interventions, including WRMSD, by means of business incentives.

4. Conclusions

The combination and modification of economic analysis methods of economic loss mathematical calculations are suitable for work-related MSD cost prediction in European enterprises. In MSD prevention and predication such cost categories should be evaluated: personnel, training, equipment, business slowdown, overhead costs. By selecting the most appropriate cost and benefit analysis tools for MSD prediction and prevention as well as ergonomics intervention it requires an understanding of the application, analysts, type of organization, data mining, and the characteristics of the cost prediction tools themselves. Important part in cost analysis is ergonomics risk assessment that influence the risk level accuracy and hence MSD prevention costs. The research will continue by

carrying out analysis of practical application of economic analysis methods in European business organizations and by studying the effects on long-term development considering also economics efficiency.

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